



Mission Confirmation Readiness Review for the Gamma-ray Large Area Space Telescope (GLAST)

October 9, 2003



GLAST: DOE and NASA Partnership



Department of Energy Office of Science

Understand the nature of matter at the most fundamental level and to explore the evolution and fate of the universe through fundamental interactions of energy, matter, time and space.

NASA - Office of Space Science

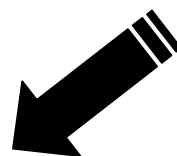
Chart the evolution of the universe, from origins to destiny

- 1. Understand the structure of the universe*
- 2. Explore the ultimate limits of gravity and and energy in the universe*
- 3. Learn how galaxies, stars and planets form, interact and evolve*

Particle physics



Astronomy/astrophysics



Gamma ray Large Area Space Telescope (GLAST)

An astro-particle physics partnership to explore the high-energy universe



GLAST is an International Mission



NASA - DoE Partnership on LAT

LAT is being built by an international team

Si Tracker: Stanford, UCSC, Japan, Italy

CsI Calorimeter: NRL, France, Sweden

Anticoincidence: GSFC

Data Acquisition System: Stanford, NRL

GBM is being built by US and Germany

Detectors: MPE



Sweden



Italy



France



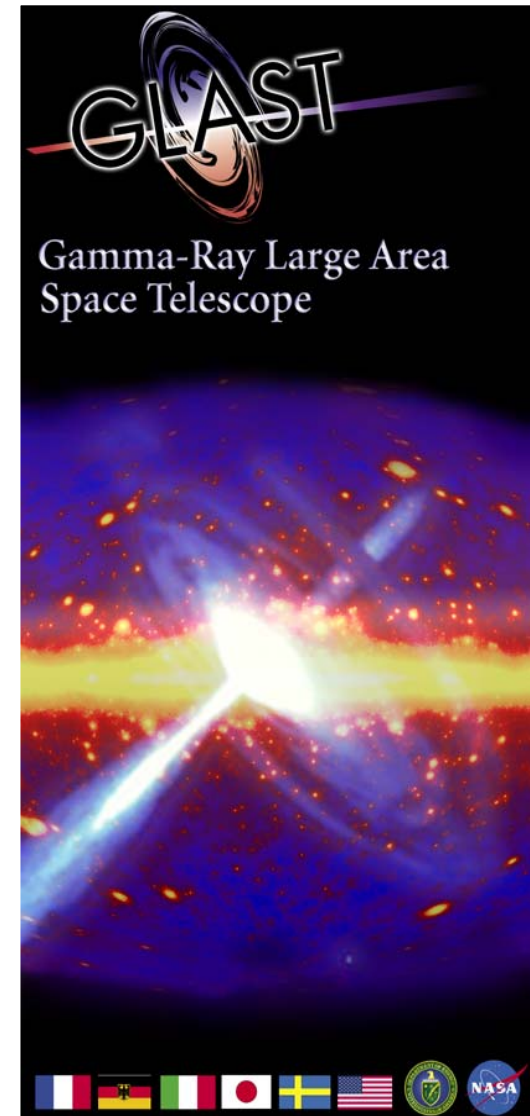
Germany



USA



Japan





Process Leading to GLAST MCR

- ▶ ***Spacecraft PDR & Spacecraft Flight Software PDR: May 5-9***
- ▶ ***Large Area Telescope CDR: May 12-15***
- ▶ ***GLAST Mission PDR/NAR***
 - *June 3-5, 2003. Simultaneous review by two independent teams.*
 - *HQ Independent Review Team (IRT)*
 - *GSFC Systems Review Office (SRO)*
- ▶ ***Briefed GSFC Management on Mission Schedule Recommendation for the Confirmation Review: July 14***
- ▶ ***Ground System System Requirements Review (SRR): July 22***
- ▶ ***HQ Astronomy and Physics Division Confirmation Briefing: Aug 14***
- ▶ ***HQ Astronomy and Physics Division Update Briefing: Sept 11***
- ▶ ***Mission Confirmation Readiness Review (MCRR): October 9***
- ▶ ***GSFC Center Director Pre-Briefing: October 29***
- ▶ ***Space Science Enterprise Deputy AA Briefing: October 31***
- ▶ ***Space Science Enterprise AA Confirmation Briefing: November 20***
- ▶ ***Agency Confirmation Review: December 3***



Purpose of the MCRR

- ▶ ***Establish Readiness of GLAST mission to proceed into implementation phase***
- ▶ ***Establish GLAST Project's readiness to proceed forward to the Enterprise and Agency Confirmation Reviews***
 - *Requirements/Success Criteria*
 - *Preliminary Designs/Margins*
 - *Implementation Approach*
 - *Schedule*
 - *Budget*
 - *Risk management/Issues*
- ▶ ***Assessments by 3 independent teams***
 - *HQ Independent Review Team (IRT)*
 - *GSFC Systems Review Office (SRO)*
 - *Resources Analysis Office (RAO)*



GLAST MCRR Agenda



- | | | | |
|----|--|--|----------------------|
| 1. | <i>Introduction</i> | <i>Kevin Grady</i> | <i>10 min</i> |
| 2. | <i>Science Overview</i> | <i>Steve Ritz</i> | <i>20 min</i> |
| 3. | <i>Mission Overview</i> | <i>Kevin Grady</i> | <i>45 min</i> |
| 4. | <i>SRO Assessment/
7120.5 Audit</i> | <i>Mark Goans/
Beth Keer</i> | <i>35 min</i> |
| 5. | <i>RAO Assessment</i> | <i>Cindy Fryer</i> | <i>25 min</i> |
| 6. | <i>IRT Assessment/
GLAST Project Response</i> | <i>Art Fuchs/
Kevin Grady</i> | <i>45 min</i> |
| 7. | <i>Discussion</i> | <i>GPMC</i> | <i>60 min</i> |



GLAST Science Overview

Steve Ritz



Outline



- ▶ ***Why γ 's? Why this energy range?***
- ▶ ***A few science topics highlights***
- ▶ ***Mission science history***
- ▶ ***Level 1 requirements***
- ▶ ***Science mission elements***
- ▶ ***Summary***

Why study γ 's?

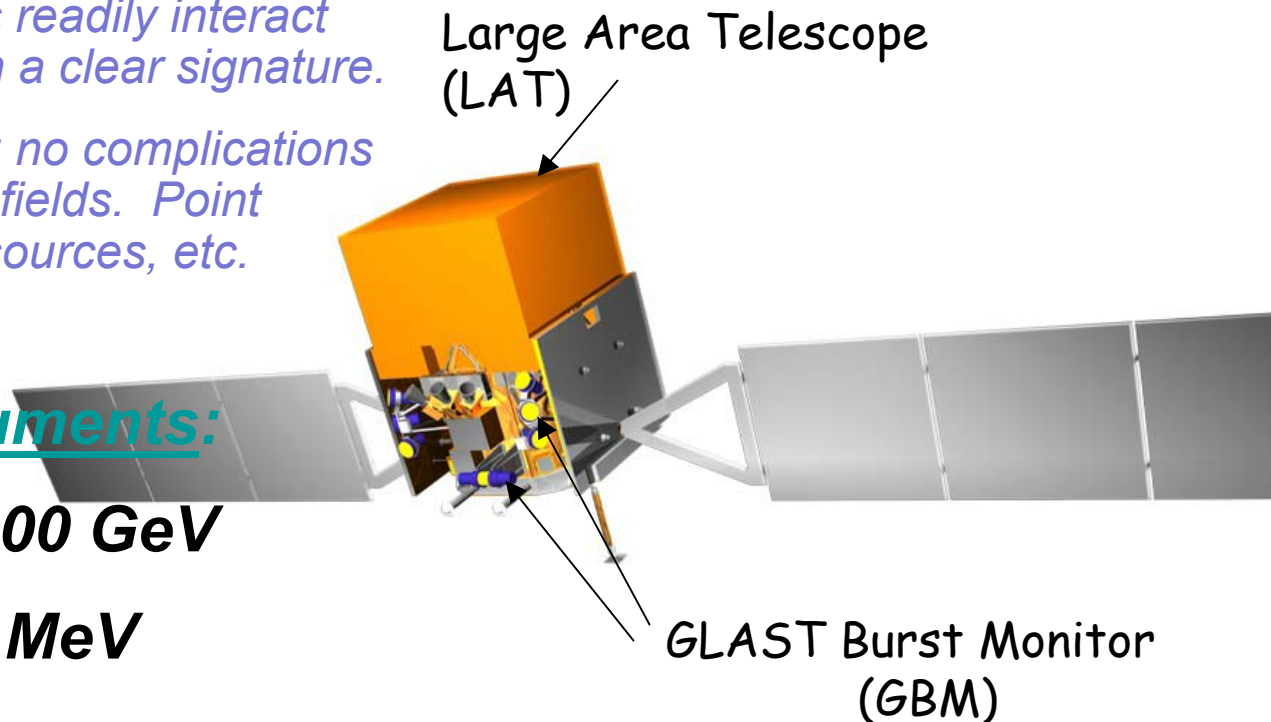
Gamma rays carry a wealth of information:

- γ rays do not interact much at their source: they offer a direct view into Nature's largest accelerators.
- similarly, the Universe is mainly transparent to γ rays: can probe cosmological volumes. Any opacity is energy-dependent.
- conversely, γ rays readily interact in detectors, with a clear signature.
- γ rays are neutral: no complications due to magnetic fields. Point directly back to sources, etc.

Two GLAST instruments:

LAT: 20 MeV – >300 GeV

GBM: 10 keV – 25 MeV





GLAST Science

GLAST will have a very broad menu that includes:

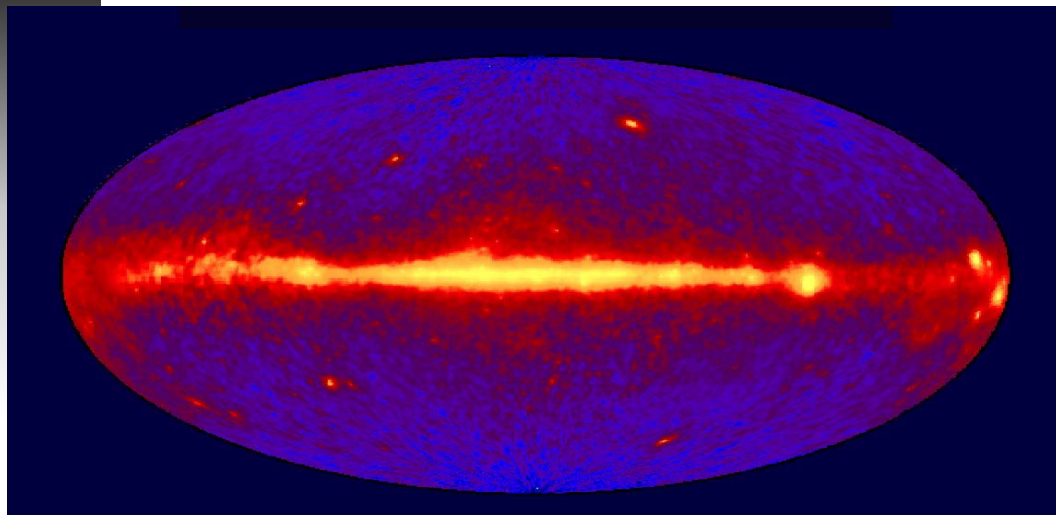
- ▶ *Systems with supermassive black holes*
- ▶ *Gamma-ray bursts (GRBs)*
- ▶ *Pulsars*
- ▶ *Solar physics*
- ▶ *Origin of Cosmic Rays*
- ▶ *Probing the era of galaxy formation*
- ▶ *Solving the mystery of the high-energy unidentified sources*
- ▶ *Discovery! Particle Dark Matter? Other relics from the Big Bang? Testing Lorentz invariance. New source classes.*

Huge increment in capabilities.

*GLAST draws the interest of both the the High Energy Particle Physics
and High Energy Astrophysics communities.*



Features of the gamma-ray sky



EGRET all-sky survey (galactic coordinates) $E > 100$ MeV

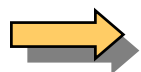
diffuse extra-galactic background
(flux $\sim 1.5 \times 10^{-5} \text{ cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$)

galactic diffuse (flux $\sim O(100)$ times larger)

high latitude (extra-galactic) point sources (typical flux from EGRET sources $O(10^{-7} - 10^{-6}) \text{ cm}^{-2} \text{ s}^{-1}$)

galactic sources (pulsars, un-ID'd)

An essential characteristic: VARIABILITY in time!



Field of view, and the ability to repoint, important for study of transients.



GLAST LAT High Energy Capabilities

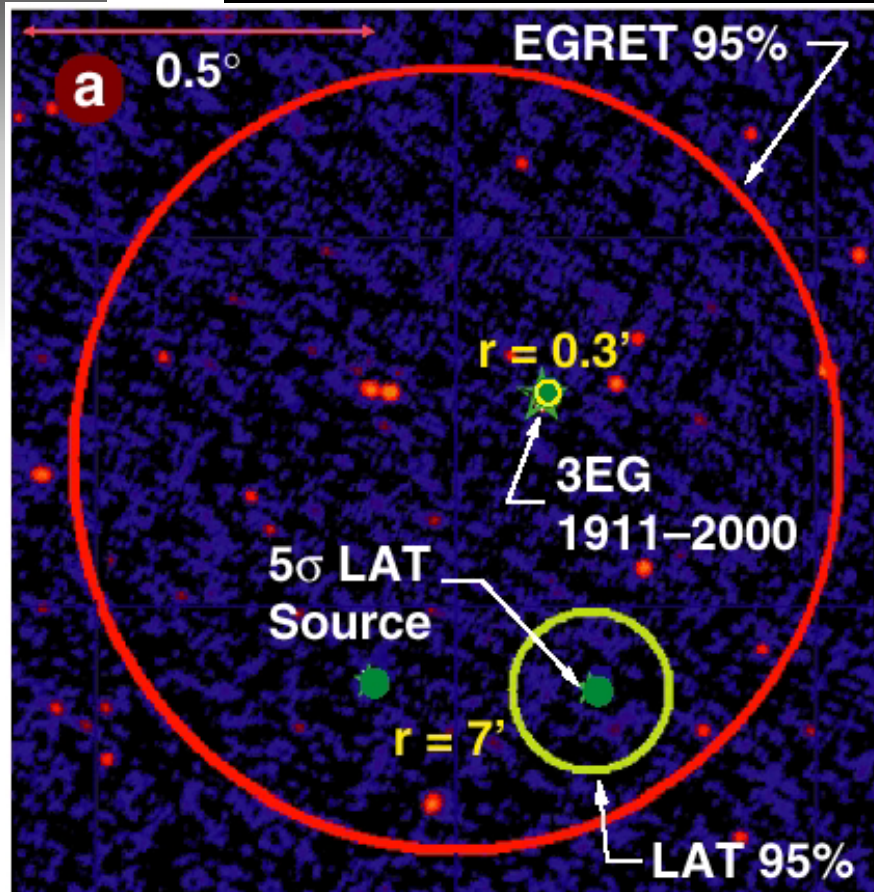


- Huge FOV (~20% of sky)
- Broadband (4 decades in energy, including unexplored region > 10 GeV)
- Unprecedented PSF for gamma rays (factor > 3 better than EGRET for $E > 1$ GeV)
- Large effective area (factor > 4 better than EGRET)
- Results in factor > 30 -100 improvement in sensitivity
- No expendables → long mission without degradation



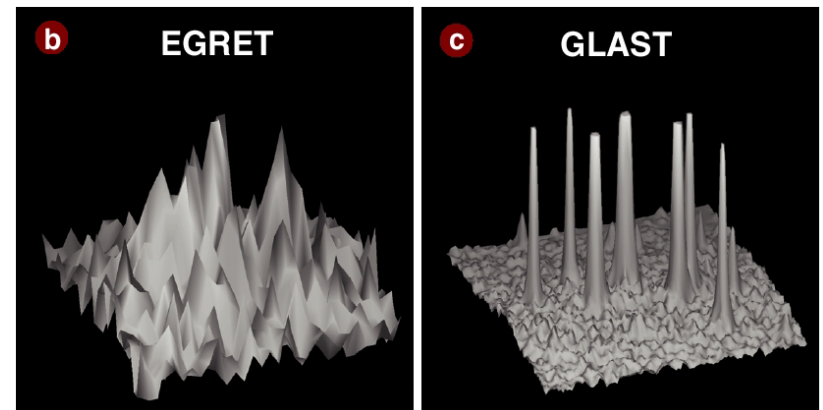
Unidentified Sources

172 of the 271 sources in the EGRET 3rd catalog are “unidentified”



- Rosat or Einstein X-ray Source
- 1.4 GHz VLA Radio Source

EGRET source position error circles are $\sim 0.5^\circ$, resulting in counterpart confusion. GLAST will provide much more accurate positions, with ~ 30 arcsec - ~ 5 arcmin localizations, depending on brightness.



Cygnus region (15x15 deg)



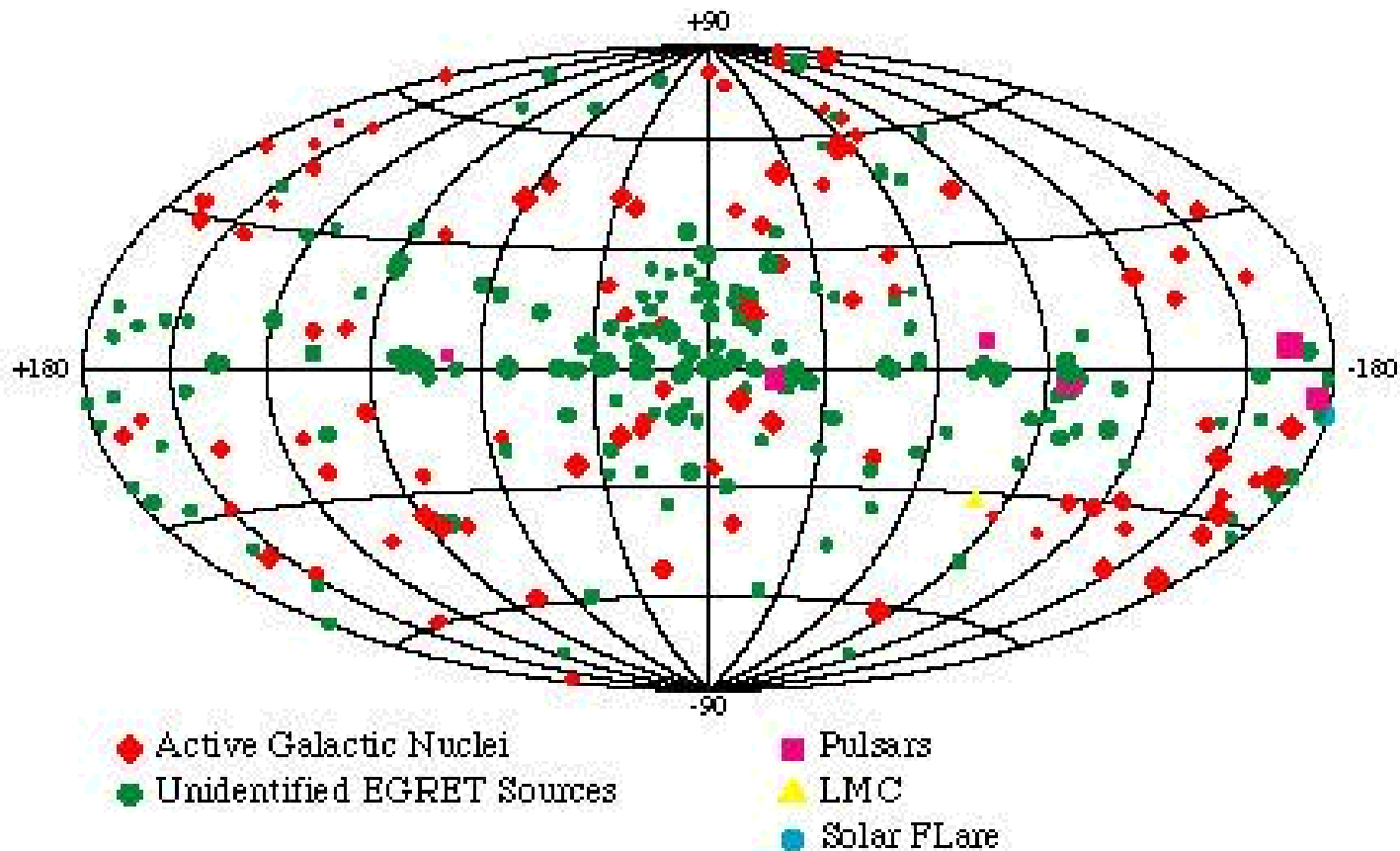
Sources



Third EGRET Catalog

$E > 100 \text{ MeV}$

EGRET 3rd
Catalog: 271
sources



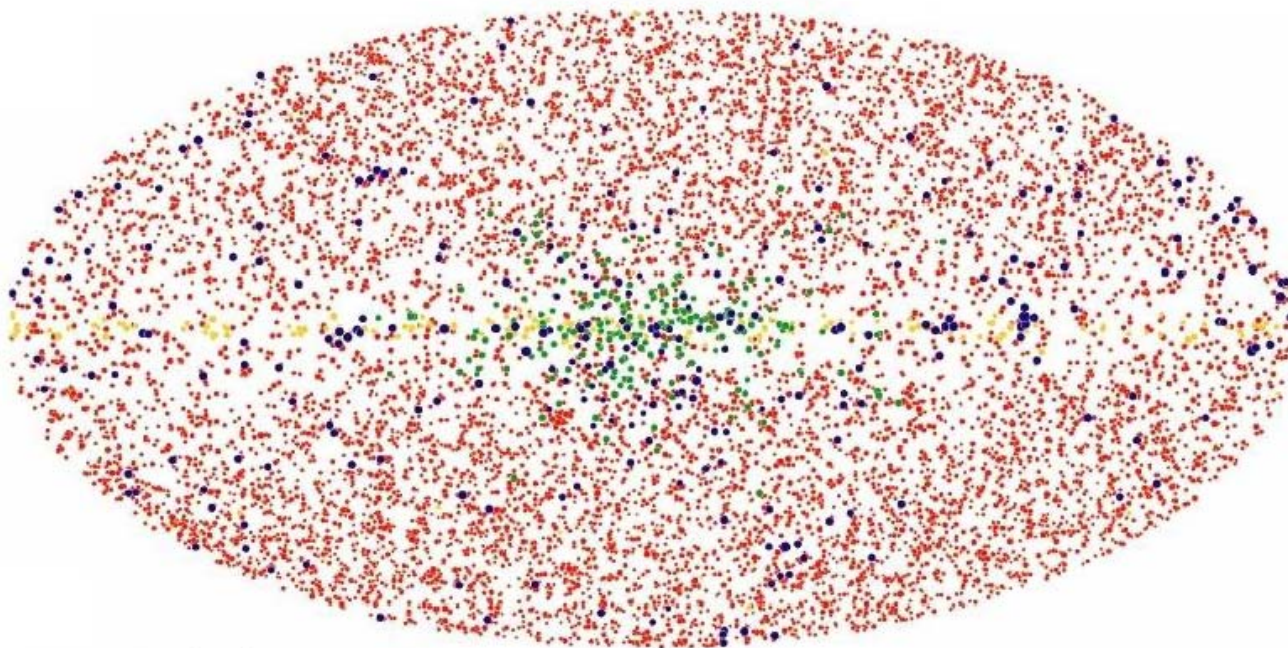


Sources



5 σ Sources from Simulated One Year All-sky Survey

LAT 1st Catalog:
>9000 sources
possible



Results of one-year
all-sky survey.
(Total: 9900 sources)

● AGN
● 3EG Catalog

● Galactic Halo
● Galactic Plane

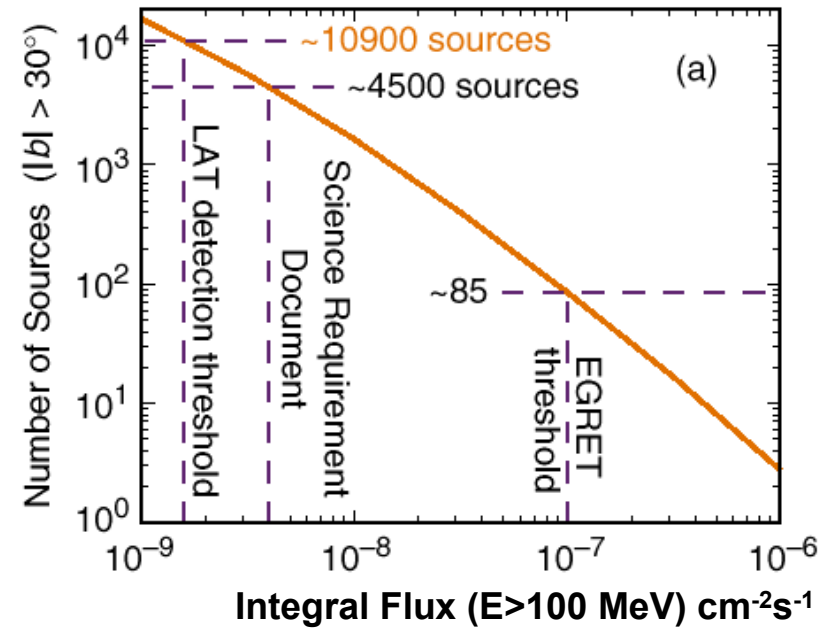


AGN: What GLAST will do

EGRET has detected ~ 70 AGN. Extrapolating, GLAST should expect to see dramatically more – many thousands:

- Allows a statistically accurate calculation of AGN contribution to the high energy diffuse extra-galactic background.
- Constrain acceleration and emission models. Correlate with other wavelength facilities. How do AGN work?
- Probe energy roll-offs with distance (light-light attenuation): info on era of galaxy formation.
- Long mission life to see weak sources and transients.

Joining the unique capabilities of GLAST with other detectors will provide a powerful tool.





GLAST Probes the Optical-UV Extragalactic Background Light

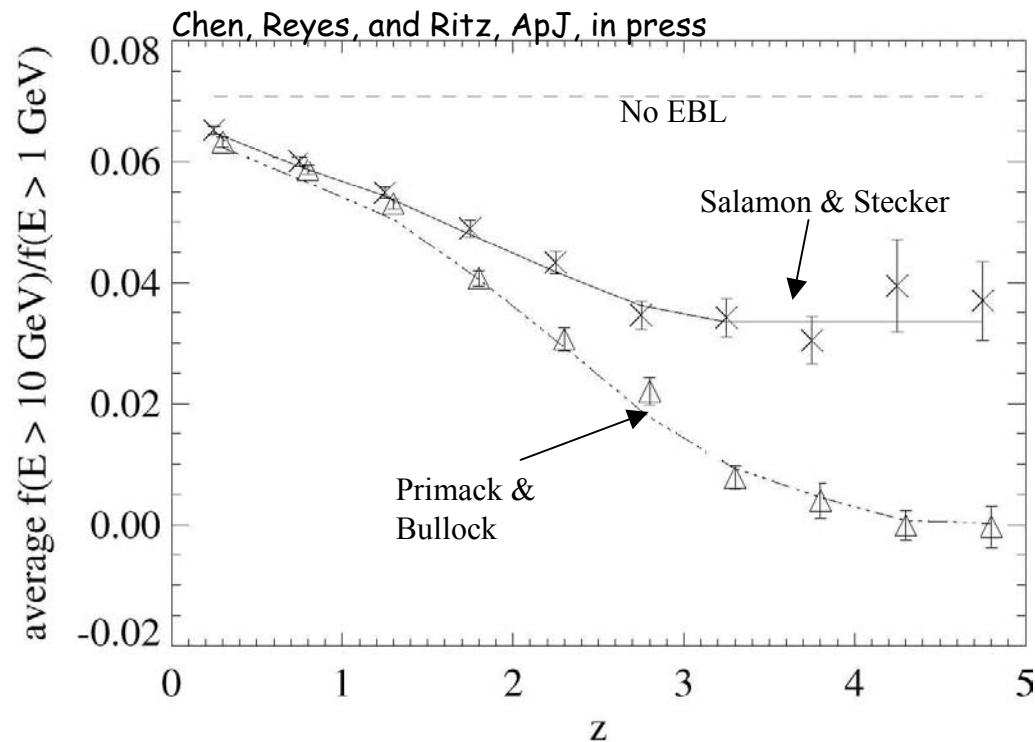


- **Important advances offered by GLAST:**

(1) thousands of blazars - instead of peculiarities of individual sources, look for systematic effects vs redshift.

(2) key energy range for cosmological distances.

- Effect is model-dependent (**this is good**):

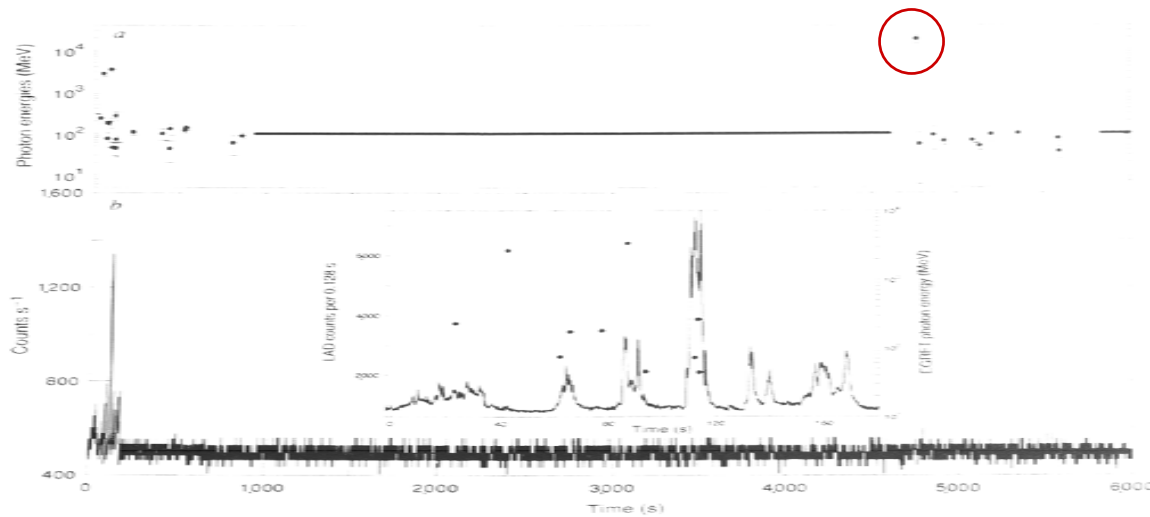


Gamma Ray Bursts

GRBs are now known to be at cosmological distances.

The question persists : What are they??

EGRET has detected very high energy emission associated with bursts, including an 18 GeV photon ~75 minutes after the start of a burst:



GLAST will provide definitive information about the high energy behavior of bursts.
LAT and GBM together will measure emission over >7 decades of energy.



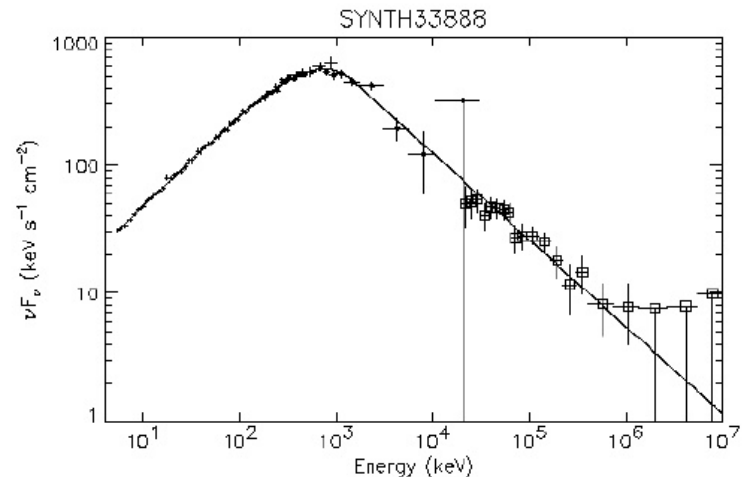
Roles of the GBM

- ▶ *provides spectra for bursts from 10 keV to 30 MeV, connecting frontier LAT high-energy measurements with more familiar energy domain;*

Simulated GBM and LAT response to time-integrated flux from bright GRB 940217

Spectral model parameters from CGRO wide-band fit

1 NaI (14 °) and 1 BGO (30 °)

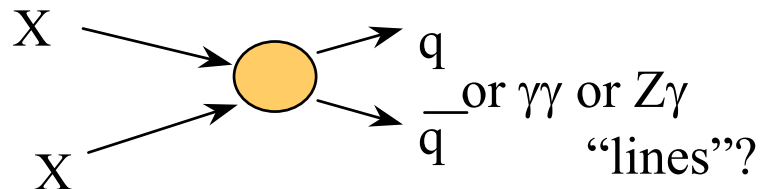


- ▶ *provides wide sky coverage (8 sr) -- enables autonomous repoint requests for exceptionally bright bursts that occur outside LAT FOV for high-energy afterglow studies (an important question from EGRET);*
- ▶ *provides burst alerts to the ground.*

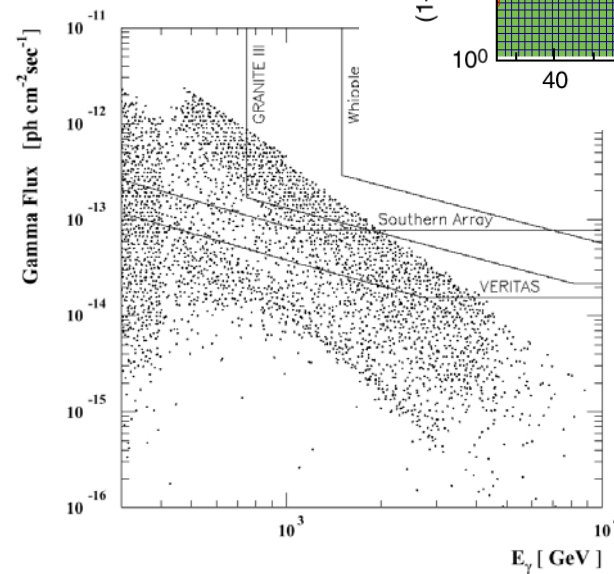
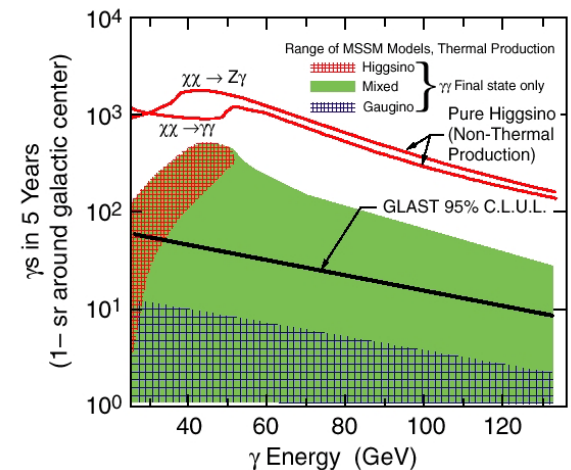


Particle Dark Matter

Some important models in particle physics could also solve the dark matter problem in astrophysics. If correct, these new particle interactions could produce an anomalous flux of gamma rays.



Just an example of what might be waiting for us to find!





Science Review History Highlights



- Selected as mission concept study, 1994 (PI: Michelson, Stanford)
- Endorsed by Gamma-Ray Astronomy Program Working Group as highest priority in gamma-ray astronomy, 1996
- Chosen as top priority (with Constellation-X) by Structure and Evolution of the Universe Subcommittee, 1997
- Reviewed by SAGENAP, presented to HEPAP, and approved by DoE, 1998
- **Science Requirements Document**, drafted by Facility Science Team, signed in July 1999.
- NASA AO: August 1999. Selections: February-March 2000.
- **GLAST is the highest-ranked Moderate Size space-based initiative in the National Academy of Sciences 2000 Decadal Survey Report.**



Level 1 Requirements Summary

<i>Quantity</i>	<i>Requirement</i>	<i>Minimum</i>
<i>Mission Lifetime</i>	<i>>5 years</i>	<i>>2 years</i>
<i>LAT High-latitude Point Source Sensitivity ($E > 100$ MeV)</i>	<i>$< 6 \times 10^{-9} \text{ cm}^{-2} \text{ s}^{-1}$</i>	<i>$< 8 \times 10^{-9} \text{ cm}^{-2} \text{ s}^{-1}$</i>
<i>LAT High-latitude Source Location Determination</i>	<i>< 0.5 arcmin</i>	<i>< 1 arcmin</i>
<i>LAT Peak Effective Area</i>	<i>$> 8000 \text{ cm}^2$</i>	<i>$> 8000 \text{ cm}^2$</i>
<i>LAT Energy Range</i>	<i>$< 20 \text{ MeV} - > 300 \text{ GeV}$</i>	<i>$< 30 \text{ MeV} - > 100 \text{ GeV}$</i>
<i>LAT Background Rejection</i>	<i>$< 10\%$ high-latitude diffuse</i>	<i>$< 20\%$ high-latitude diffuse</i>
<i>LAT Energy Resolution (on-axis, 100 MeV – 10 GeV)</i>	<i>$< 10\%$</i>	<i>$< 20\%$</i>
<i>LAT Field of View</i>	<i>$> 2 \text{ sr}$</i>	<i>$> 1.5 \text{ sr}$</i>



Science Mission Elements

► **Science Working Group (SWG)**

- *Membership includes the Interdisciplinary Scientists (IDS)*
- *Bi-monthly telecons and ~bi-annual sit-down meetings, along with science symposia to engage the community.*

► **Users Committee**

- *independent of the SWG. External review/feedback on science tools planning and progress.*
- *includes members from both the astrophysics and high-energy particle physics communities who are likely users of GLAST data.*

► **GLAST Science Support Center (GSSC)**

- *Located at Goddard. Supports guest observer program, provides training workshops, provides data and software to community, archives through to HEASARC, joint software development with Instrument Teams.*



Operations Phases, Guest Observers, Data

- ▶ ***After the initial on-orbit checkout, verification, and calibrations, the first year of science operations will be an all-sky survey.***
 - *first year data used for detailed instrument characterization, refinement of the alignment, and key projects (source catalog, diffuse background models, etc.) needed by the community*
 - *data policy in Project Data Management Plan (PDMP)*
 - *data on transients will be released, with caveats*
 - *repoints for bright bursts and burst alerts enabled*
 - *extraordinary ToO's supported*
 - *limited guest observer program*
 - *workshops for guest observers on science tools and mission characteristics for proposal preparation*
- ▶ ***Observing plan in subsequent years driven by guest observer proposal selections by peer review. All data released through the science support center (GSSC).***



Summary

- ▶ ***GLAST will address many important questions:***
 - *What is going on around black holes? How do Nature's most powerful accelerators work?*
 - *What are the unidentified sources found by EGRET?*
 - *What is the origin of the diffuse background?*
 - *What is the origin of cosmic rays?*
 - *What is the high energy behavior of gamma ray bursts?*
 - *When did galaxies form?*
 - *What else out there is shining gamma rays? Are there high-energy relics from the Big Bang? Are there further surprises in the poorly measured energy region?*
- ▶ ***Large menu of “bread and butter” science, and large discovery potential.***
- ▶ ***Science requirements are mature and stable.***
- ▶ ***GLAST is part of the bigger picture of experiments at the interface between particle physics and astrophysics.***

GLAST will provide a wealth of important new data to the science community.



GLAST Mission Overview

Kevin Grady

GLAST: Expand our understanding of the gamma ray universe



Identify dark matter and learn how it shapes galaxies and systems of galaxies

Discover the sources of gamma ray bursts and high energy cosmic rays

Determine the energy content of the universe

Reveal the nature of cosmic jets and relativistic flows

Test the general theory of relativity near black holes and in the early universe, and search for new physical laws



Mission Overview Outline



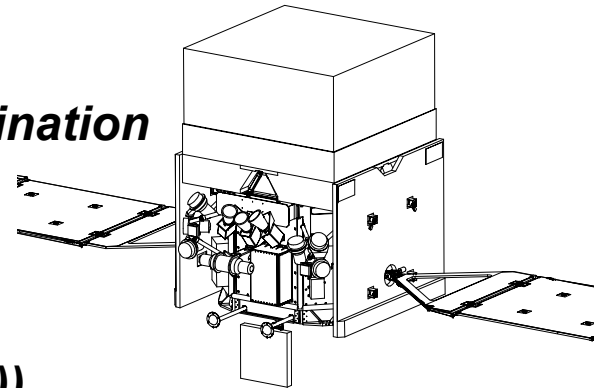
- ▶ *GLAST System Overview and Requirements*
- ▶ *Instrument Overview*
- ▶ *Implementation Approach*
- ▶ *System Margins*
- ▶ *Status*
- ▶ *Re-entry Debris Strategy*
- ▶ *Top Ten/Issues*
- ▶ *Risks*
- ▶ *Schedule and GLAST LRD*
- ▶ *Budget*
- ▶ *Organization*



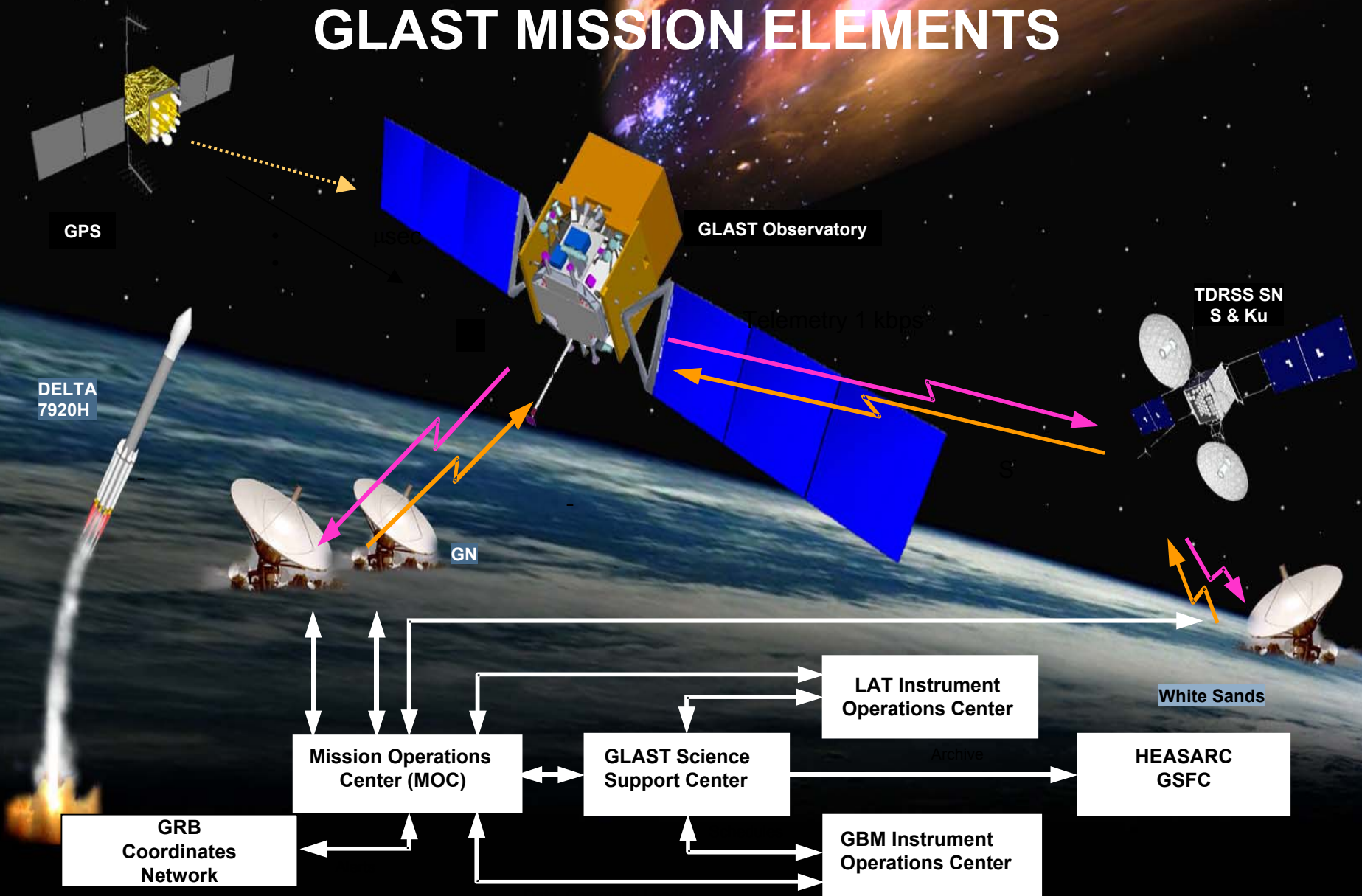
GLAST MISSION SUMMARY



- ▶ **GLAST:** *Gamma-Ray Large Area Space Telescope*
- ▶ **Objective:** *Larger field of view (FOV), higher sensitivity, and broader energy detection range than any previously flown gamma-ray mission. Affords scientists the unprecedented opportunity to sample the history of the universe, a variety of high energy astrophysical phenomena, and many of the little understood features of the sky*
- ▶ **Mission Duration:** *5 yrs (10 yr ops budget)*
- ▶ **Orbit:** *565 km Circular, 28.5° Inclination*
- ▶ **Launch Date:** *February 2007*
- ▶ **Launch Vehicle:** *Delta 2920H-10*
- ▶ **Launch Site:** *CCAS (Eastern Range (ER))*
- ▶ **TDRSS (SN):** *S-Band Single Access or Multiple Access
Ku-Band Single Access*
- ▶ **NASA Cost:** *655 M (full cost including ops)/597 M*



GLAST MISSION ELEMENTS



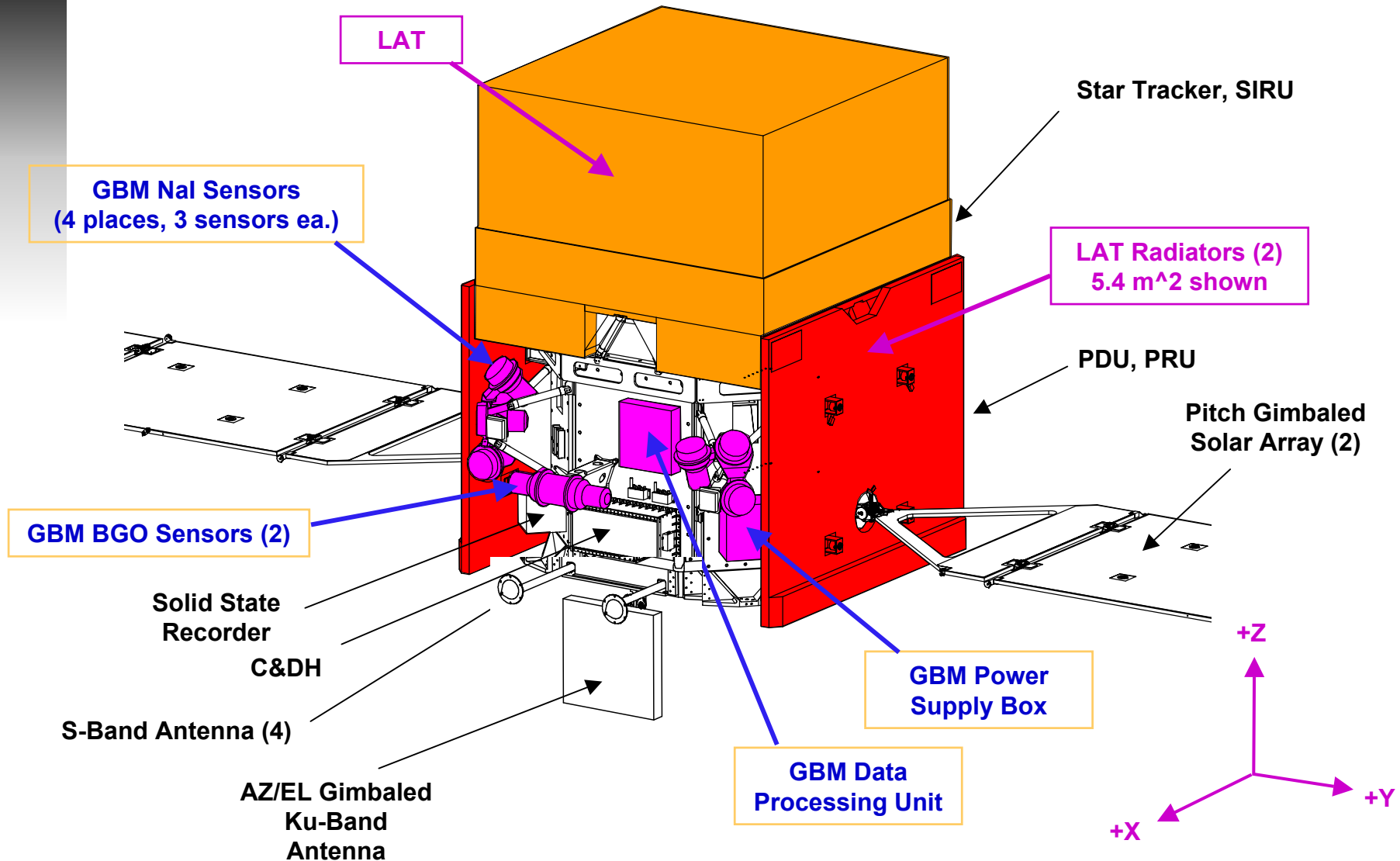


Level 1 Requirements

- ▶ ***Mission Life: design – 5 years, minimum – 2 years***
- ▶ ***Full mission success***
 - *One year sky survey; four years of observations of selected investigations*
- ▶ ***Minimum mission success***
 - *One year sky survey; one year of observations of selected investigations*
- ▶ ***GLAST Science Level 1 Requirements*** *(summarized in science presentation)*
 - *Effective area, energy range, source location*
- ▶ ***Reliability: no credible single point failure***
- ▶ ***Science planning, data processing and reduction, archiving and distribution of data products***
- ▶ ***Launch on an MELV***
- ▶ ***Execute a national-scale Education and Public Outreach program***



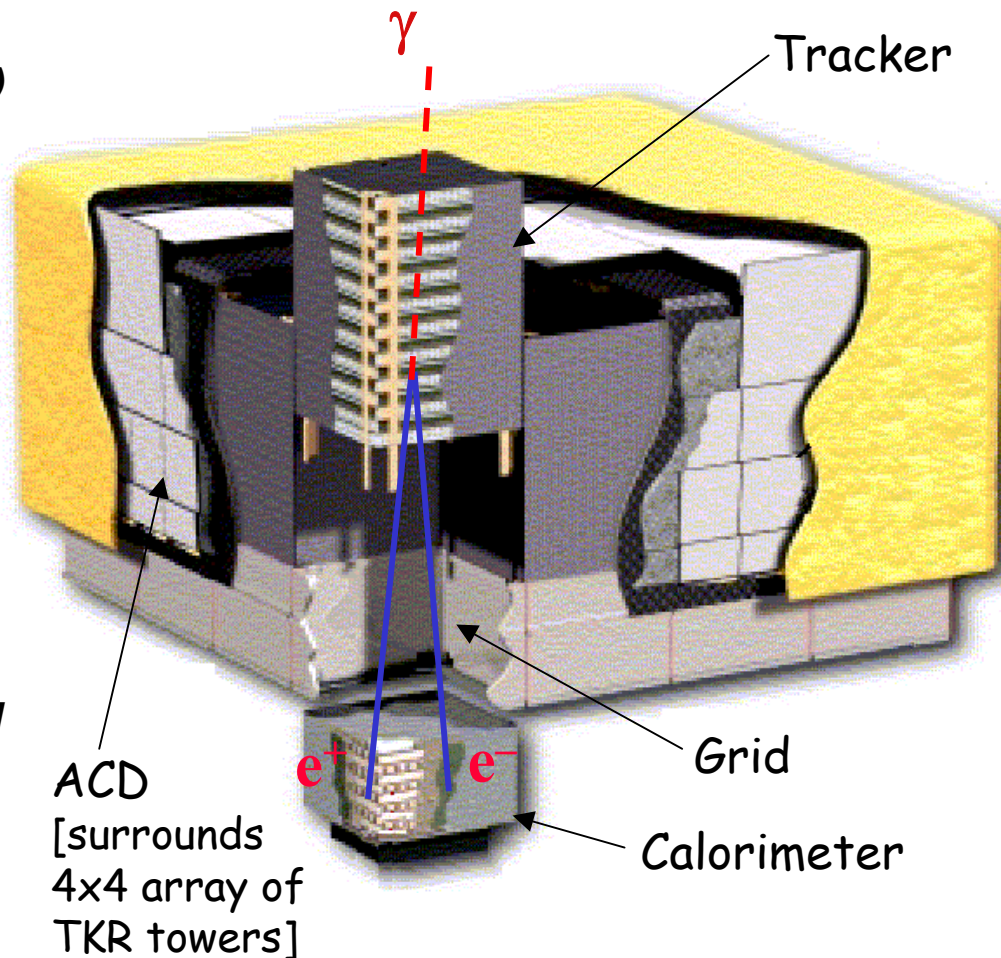
GLAST Observatory





LAT Design Overview

- ▶ **Precision Si-strip Tracker (TKR)**
18 XY tracking planes. Single-sided silicon strip detectors (228 μm pitch) Measure the photon direction; gamma ID. *Italy/Japan/SLAC/UCSC*
- ▶ **Hodoscopic CsI Calorimeter(CAL)**
Array of 1536 CsI(Tl) crystals in 8 layers. Measure the photon energy; image the shower. *NRL/Sweden/France*
- ▶ **Segmented Anticoincidence Detector (ACD)** 89 plastic scintillator tiles. Reject background of charged cosmic rays; segmentation removes self-veto effects at high energy. *GSFC*
- ▶ **Electronics System Includes** flexible, robust hardware trigger and software filters. *SLAC/NRL*
- ▶ **Mechanical System** includes LAT Grid, thermal management (radiators, x-LAT plate with heat pipes, and ancillaries) *SLAC/LM*



Systems work together to identify and measure the flux of cosmic gamma rays with energy 20 MeV - >300 GeV.

GLAST BURST MONITOR

Mass: 97 kg

Instrument Size: See diagrams (at right)

Science FOV: Targets 0-120° from +Z; >25° apart; FOV must be covered by ≥ 3 NaI sensors within 80°, with Ps >95%; one BGO sensor visible with Ps >95%.

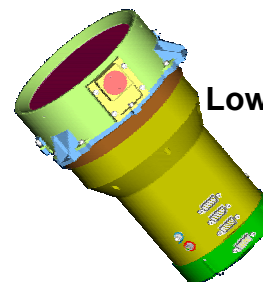
Mounting: S/C supported.

Key GBM Accommodation Requirements:

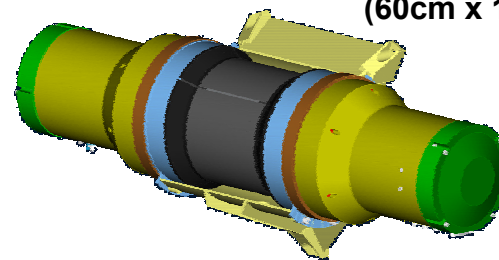
12 Sodium Iodide (NaI) and 2 Bismuth Germanate (BGO) detectors distributed around spacecraft bus. **Germany/DLR/MPE/DJO**

Data Processing Unit located on +X spacecraft panel. **MSFC/SwRI**

GBM Power Supply mounted on spacecraft. **Germany/DLR/MPE/DJO**

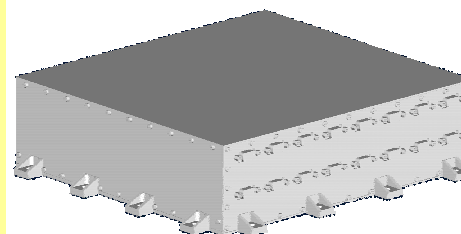


12 NaI
Low Energy Detectors
(26cm x 18cm)

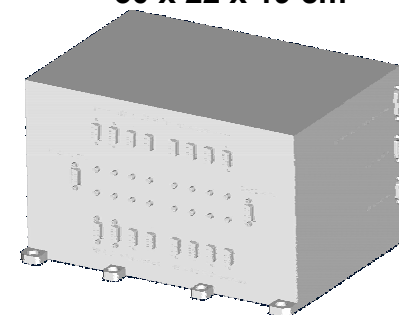


2 BGO
High Energy Detectors
(60cm x 18cm)

Data Processing Unit
30 x 30 x 10 cm



Power Supply Box
30 x 22 x 19 cm





Implementation Approach

Element	Acquisition Method	Developer
Large Area Telescope and LAT Operations Center PI: Peter Michelson	Stanford University PI with host laboratory SLAC selected through NASA AO. Joint NASA/DOE funding with foreign participation.	Responsibility of SU/SLAC with international collaboration. SU/SLAC contracts and all except 1 MOU in place. NASA/DOE IA in place.
GLAST Burst Monitor and GBM Operations Center	MSFC PI selected through NASA AO. PI: Chip Meegan	MSFC responsibility with German participation. German LOA signed.
Spacecraft	Rapid Spacecraft Development Office firm, fixed price procurement.	Spectrum Astro, Inc.
Science Support Center	HQ selection.	GSFC In-house development.
Interdisciplinary Scientist	HQ selection via AO.	Dr. Charles D. Dermer - Analyzing and Modeling GLAST Science. Prof. Brenda Dingus - GLAST: The First GeV All-Sky Monitor. Dr. Martin Pohl - Modelling the Diffuse Galactic Gamma-ray Emission. Prof. Stephen E. Thorsett - Pulsar Observations in Support of GLAST
Guest Observers	HQ selection via NASA Solicitation.	HQ selection.
Mission Operations Center	GSFC Sole Source (8A)	8A (ANC) contract to be awarded December 03.
Data Routing	TDRSS Space Network.	Existing NASA services
Launch Vehicle	KSC NLS Contract	KSC/Boeing



Agreement Status

GLAST Agreement Matrix

PARTNERING ORGANIZATION	PROJECT RESPONSIBILITY	SPONSORING ORGANIZATION					CURRENT STATUS
		NASA HQ	DOE HQ	GLAST PROJECT (GSFC)	LAT PROJECT (SU/SLAC)	GBM / MSFC	
DOE HQ	LAT Program funding	MOU / IA (signed)					All agreements are in place.
Project / GSFC	GLAST Mission	Program Plan (Draft)			Contract NAS5-00147	GBM Project Plan	All agreements are in place.
LAT Project (SU / SLAC)	LAT Instrument	AO Selection	SLAC Program authority	Contract NAS5-00147			All agreements are in place.
Italy / ASI / INFN	LAT Si detectors, Tracker fabrication, assembly & test.	LOA			MOA		Italian LOA is in Italy for review. >470 flight ladders produced.
France / CNRS / IN2P3 / Ecole Polytechnique	LAT Calorimeter structure design and fabrication.	LOA			MOA (signed)		Draft LOA between NASA and CNRS at HQ Code I for review. IN2P3 continuing effort.
France / CEA / DAPNIA	LAT Calorimeter CDE's, & Photodiodes	LOA			MOA (signed)		Draft LOA between NASA and CEA at HQ Code I for review. Backup production of CDEs in US being exercised. LOA covers work already completed by CEA.
Japan / JGC	LAT Si detectors (5000 pcs)	LOA			MOA (signed)		Draft LOA at HQ. Detectors continue to be delivered.
Sweden / KTH	LAT CsI crystals	LOA			MOA (signed)		Draft LOA at HQ. Full funding received. EM crystals delivered.
NRL	LAT Calorimeter electronics, management and integration & test, DAQ.			NDPR S-15633-Y	MOA (signed)		All agreements are in place.
GSFC / AETD	LAT Anti-Coincidence Detector (ACD)			Funding Transfer	MOA (signed)		All agreements are in place.
UCSC / SCIPP	LAT Tracker management, Tracker cable plant, electronics design, fab and test.				MOA (signed)		All agreements are in place.
University of Washington	LAT Science Analysis Software.				MOA (signed)		All agreements are in place.
GBM Project / MSFC	GBM Instrument	AO Selection		Suballot/ POP			All agreements are in place.
Germany / DRL	GBM NaI and BGO detector assemblies.	LOA (signed)					All agreements are in place.

As of 5/26/03

GLASTAgreement Matrix.xls

Unsigned

Completed



Key System Margins

<i>Technical Performance Metric</i>	<i>Requirement</i>	<i>Estimate</i>	<i>Margin</i>	
<i>Observatory Mass (kg)</i>	<i>4627</i>	<i>4062</i>	<i>14%</i>	←
<i>Observatory Axial Center of Gravity (m)</i>	<i>1.37</i>	<i>1.35</i>	<i>0.02</i>	
<i>Observatory (Pointed Observation Mode) Orbit Average Power (W)</i>	<i>1700</i>	<i>1373</i>	<i>24%</i>	
<i>Observatory Pointing Knowledge (arc sec)</i>	<i>10.0</i>	<i>6.9</i>	<i>1.4 x</i>	←
<i>SC Attitude Determination Error for GBM (arcmin)</i>	<i>5.0</i>	<i>2.17</i>	<i>2.3 x</i>	
<i>Data Storage Capacity (Gbits)</i>	<i>46.45</i>	<i>96 (BOL)</i>	<i>107%</i>	
<i>Observatory Lateral Frequency (Hz)</i>	<i>>12</i>	<i>15.5</i>	<i>29%</i>	
<i>Ku-band D/L [40 Mbps] (dB)</i>	<i>3</i>	<i>3.08</i>	<i>0.08 dB</i>	
<i>S-band U/L [GN 2 kbps] (dB)</i>	<i>0</i>	<i>39.0</i>	<i>39.0 dB</i>	
<i>S-band D/L [GN 2.5 Mbps] (dB)</i>	<i>0</i>	<i>10.5</i>	<i>10.5 dB</i>	
<i>S-band Fwd [TDRSS 250 bps MA] (dB)</i>	<i>0</i>	<i>2.2</i>	<i>2.2 dB</i>	
<i>S-band Rtn [TDRSS 1 kbps MA] (dB)</i>	<i>0</i>	<i>1.9</i>	<i>1.9 dB</i>	
<i>S-band Fwd [TDRSS 4 kbps SA] (dB)</i>	<i>0</i>	<i>4.7</i>	<i>4.7 dB</i>	
<i>S-band Rtn [TDRSS 1 kbps SA] (dB)</i>	<i>0</i>	<i>10.7</i>	<i>10.7 dB</i>	

NOTE: Performance Estimate values are expressed as CBE – Current Best Estimate



MASS Budget Margins

		<i>mass (kg)</i>			
		<i>Allocation</i>	<i>Estimate</i>	<i>Margin</i>	<i>%</i>
►	<i>Dry SC</i>	1169	907	262	29
►	<i>SC including propellant</i>	1530	1267	263	21
►	<i>LAT</i>	3000	2711	289	11 <small>(see note)</small>
►	<i>GBM</i>	97	84	13	15
►	<i>Observatory mass</i>	4627	4062	565	14

- *49.3% of LAT mass estimate is measured, effectively making the margin on the non-measured portion of the LAT 21%*
- *CLA analysis is expected to increase allowable CG vs LV throw weight, increasing available mass margin.*
- *Delta II Heavy throw weight with cg at 1.37 m = 4627 kg (moment limited) . Mitigations include increasing PAF capability.*



Observatory Pointing Knowledge Requirement

<i>Allocation</i> (arc-sec)	<i>Current Best Estimate</i> (MPDR value)	<i>Margin</i>
10.0	6.9	1.4x

- *Pre-MPDR, Spectrum and SLAC performed piecewise analysis to determine individual contributions to the pointing knowledge performance*
- *STOP analysis initiated post-MPDR to assess observatory-level performance*
 - *Completed Cycle 1 analysis (unit thermal gradients applied to delta-PDR observatory models) results consistent with estimates*
 - *Cycle 2 analysis in progress using interim CDR models (12/03)*
 - *Cycle 3 will provide definitive performance using CDR models run against worst-case thermal scenarios (02/04)*
- *Science Working Group has performed initial assessment of relaxing the pointing knowledge requirement*
 - *Results in degradation in source location determination resolution / accuracy*
 - *Relaxation not now required but would be re-considered if required by further analysis or test*



STATUS/RECENT PROGRESS



- ▶ **Conducted extensive LAT CDR subsystem peer reviews (January through March 2003)**
- ▶ **Conducted LAT CDR/CD-3 Review May 12-16.**
 - *Developed designs to resolve 2 of the 3 mechanical issues and an alternate plan to the 1 major programmatic issue (CNES withdrawal). Tracker EM environmental test is the remaining open CDR mechanical lien.*
 - *Completed review of LAT parts screening and qualification with mission assurance and AETD*
- ▶ **GBM instrument completed CDR for electronics and flight software.**
 - *CDR for German contributions planned for December 2003. System CDR planned for January 2004. EM detectors and DPU being tested.*
- ▶ **Spacecraft contract awarded to Spectrum Astro Inc. August 2002.**
 - *PDR and Flight Software PDR May 5-8.*
 - *Completed series of flight software peer reviews.*
 - *Construction continuing ahead of schedule for Spectrum Astro's new integration and test facility: "Factory of the Future".*
- ▶ **Ground System SRR completed for all GLAST ground elements in July 2003**



STATUS/RECENT PROGRESS (cont.)



- ▶ ***Completed Ku-band science downlink trade study in response to the withdrawal of availability (X-band upgrades not funded) of the Italian Malindi ground station***
 - *Performance and LCC benefits for utilizing TDRSS Space Network Ku-band service. Ku-band is new baseline.*
- ▶ ***GLAST launch services: will utilize NASA Launch Services (NLS) contract to procure Delta 2920H launch vehicle***
- ▶ ***Completed GSFC and JSC orbital debris assessments***
 - *Results indicate that the GLAST debris casualty area is below the threshold for controlled re-entry with the implementation of 4 “design for demise” changes. More discussion to follow.*
- ▶ ***Signed IV&V agreement for LAT flight software and spacecraft assessment.***
- ▶ ***Conducted GLAST Mission Preliminary Design Review and Non-Advocate Review on June 3-5.***
- ▶ ***Completed GLAST mission schedule and budget assessment and concurrence with Astronomy and Physics Division***
 - *Drivers: CNES withdrawal, Malindi unavailability, LAT Technical issues, overall mission schedule risk. More discussion to follow.*



GLAST Orbital Debris Assessment/Mitigation Status

- ▶ ***GLAST Project has completed the activities necessary to make a recommendation as to how to comply with NASA Safety Standard 1740.14 (Orbital Debris)***
 - *Assumes new kinetic energy guideline & human casualty probability*
 - *“The potential for human casualty is assumed for any object with an impacting kinetic energy in excess of 15 Joules.”*
- ▶ ***JSC completed ORSAT analyses to determine the surviving components on the GLAST observatory***
 - *JSC also verified the effectiveness of potential design changes to reduce the amount of surviving debris*
- ▶ ***GLAST Project is implementing the following low-risk modifications to the baseline design to reduce surviving debris***
 1. *Cut thick LAT tracker foils*
 2. *Segment LAT micro-meteoroid debris shield*
 3. *Change spacecraft optical bench strut material from Titanium to graphite epoxy*
 4. *Change LAT mounting flexure cross section to make them demise on reentry*
 5. *Take advantage of change of science downlink from X-band to Ku-band*
 6. *Defer - Removal of the propulsion system*



GLAST Orbital Debris Assessment/Mitigation Status

- ▶ ***The JSC re-entry debris (ORSAT) results indicate that the GLAST mission is in family with past GSFC missions that had no controlled-reentry capability***
 - *DCA = 12.8 m² with propulsion system, DCA = 5.0 m² without propulsion system (based on 78 km break-up scenario)*
 - *Prop system removal makes GLAST compliant for un-controlled re-entry*
 - *Increases mass margin, simplifies spacecraft, reduces surviving debris*
 - *Additional redundancy not required*
 - * *JSC examined a lower break-up altitude (73 Km) in their final report and the DCA increased by 3.1 m². Project is refining the modelling of these 3 additional items with JSC.*
- ▶ ***Recommendations result in a mission that meets NASA Safety Standard 1740.14 guidelines without relying on controlled reentry***
 - *Greater safety, simplicity, reliability, cost savings: Improves Overall Mission*
- ▶ ***Project is proceeding with the “Design for Demise” approach***
 - *However retain propulsion module in the GLAST design until the safety standard guidelines changes are approved*



Major Changes Since MPDR

► **Observatory**

- *Utilize Ku band SN link (TDRSS) for science data return.*
- *Orbit Altitude changed to 565 km since mission lifetime prediction less than 5 years at worst case launch dispersion and worst case solar cycle.*

► **4 “Design for Demise” Changes**

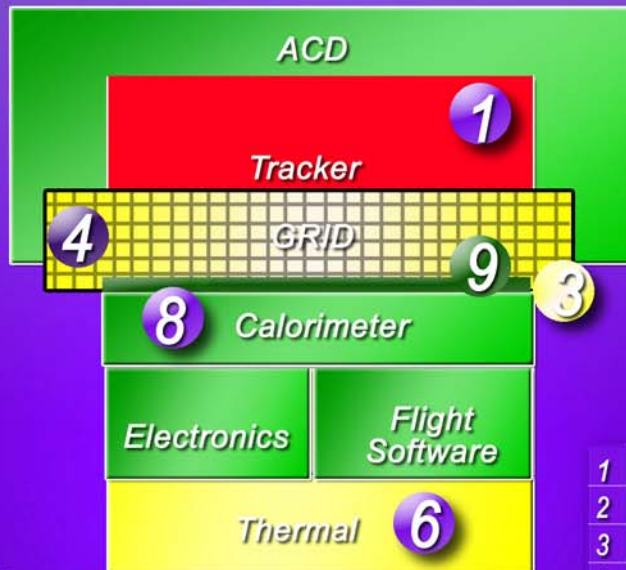
- *Slit LAT tracker thick foils to effectively cut them in half.*
- *Change spacecraft optical bench strut material from Titanium to graphite epoxy.*
- *Change LAT mounting flexure cross section to make them demise on reentry.*
- *Segment ACD Micrometeriod Shield to allow for demise.*

► **LAT**

- *Hard mount of electronics boxes on cross-LAT plate.*
- *Shear plates added at calorimeter to grid interfaces.*



Gamma Ray Burst Monitor



2 5 10 Large Area Telescope



Spacecraft

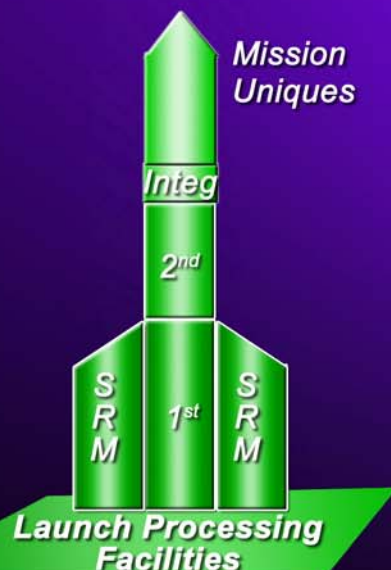


Science Data Processing

- 1 LAT Tracker EM Completion
- 2 Unsigned Letters of Agreement
- 3 LAT Stress Analysis Exceedences
- 4 LAT Mech/Thermal
- 5 CLA Results Increased LFs
- 6 E-Box/X-LAT Plate
- 7 ETE Pointing Analysis
- 8 CDE Production
- 9 Cal/Grid Mechanical I/F
- 10 GLAST Baseline Schedule



Mission Operations Center



Color Key

- Significant Problem
- Minor Problem
- On Track
- Completed/Delivered

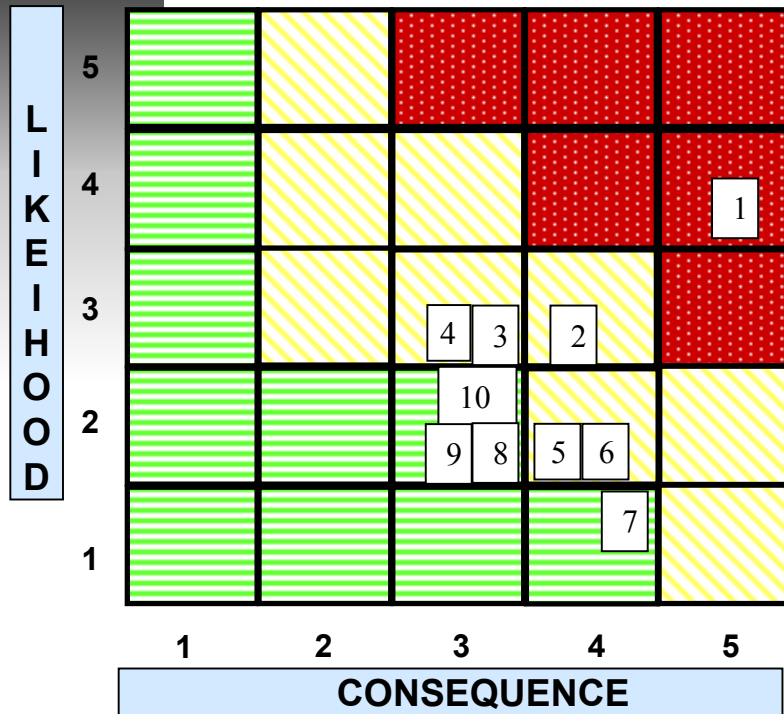
Gamma-ray Large Area Space Telescope

Project Issues - 10/01/03





GLAST Top Risks



Rank & Trend	Risk ID	Approach	Risk Title
1 ↔	000180	M	If the Tracker structure does not pass the qualification test; then a major impact to the LAT delivery schedule will occur.
2 ↔	000205	M	If LAT parts and vendor orders are completed late, then flight production schedules will be extended, and delivery of LAT subsystems delayed.
3 ↔	000130	M	If LAT FSW Requirements; processes; and Schedule are not well defined; then an impact to the LAT Inst. delivery is likely.
4 ↔	000215	M	If ASICs fail to meet requirements then LAT delivery could be delayed
5 ↔	000060	M	If LV mechanical resonance @ MECO is not well defined, then this may result in added design work and testing.
6 ↔	000200	M	If a critical component failure occurs in a LAT tower after LAT integration, then the high replication factor of the towers could result in significant schedule impact.
7 ↔	000160	M	If there is an anomaly with Solar Array deployment; then mission failure could result.
8 ↔	000190	M	If error occurs during manufacturing of the grid, then a delay in the start of LAT integration and test could result.
9 ↔	000135	M	If the Mission Mass Margin is insufficient; then budget and schedule resources may need to be expended to correct CG.
10 ↔	000185	M	If Atomic Oxygen Erosion of Solar Array Kapton occurs, then full mission life may not be achievable

Criticality

L x C Trend

Approach

High



Decreasing (Improving)

M - Mitigate

Med



Increasing (Worsening)

W - Watch

Low



Unchanged

A - Accept



New Since Last Period

R - Research



GLAST Schedule



Recent Events

- ▶ ***The LAT CDR Review Team and the NAR IRT identified the LAT schedule as the most significant risk to the GLAST mission:***
 - *LAT CDR Review Team: “The review team is not comfortable with the schedule or contingency.”*
 - *NAR IRT: Schedule identified as the No. 1 finding. “Significant risk in the delivery of the LAT instrument on schedule.”*
- ▶ ***As a result of the CNES decision to withdraw from the LAT collaboration all of the calorimeter schedule float was eroded.***
 - *Loss of the French funding and cost growth in other subsystems resulted in a schedule and budget rebaseline assessment by the LAT Team*
- ▶ ***In light of the challenges the LAT faced as well as the unique characteristics of the LAT, the Project made an assessment of the baseline mission schedule in preparation for the NAR***
 - *The Project concluded that the baseline September 2006 LRD was high risk and recommended that additional funded schedule reserve be baselined with confirmation*



Process Leading to LAT Rebaseline

- ▶ *LAT CDR/CD-3: May 12-16*
- ▶ *SLAC Director's Assessment: May 19-21*
- ▶ *GLAST Mission PDR/NAR: June 3-5*
- ▶ *LAT Team Requirements Meeting: June 12-13*
- ▶ *Pre-JOG Meeting: June 24*
- ▶ *GSFC Management Briefing: July 14*
- ▶ *JOG Meeting: July 16*
- ▶ *Director's Review at SLAC: July 21*
- ▶ *DOE Review: July 31*
- ▶ *JOG Telecon: August 11*
- ▶ *NASA A & P Division Confirmation Briefing: Aug 14*
- ▶ *DOE Acquisition Board Rebaseline Approval: Aug 28*
- ▶ *NASA Astronomy and Physics Division Briefing Update: Sept 11*



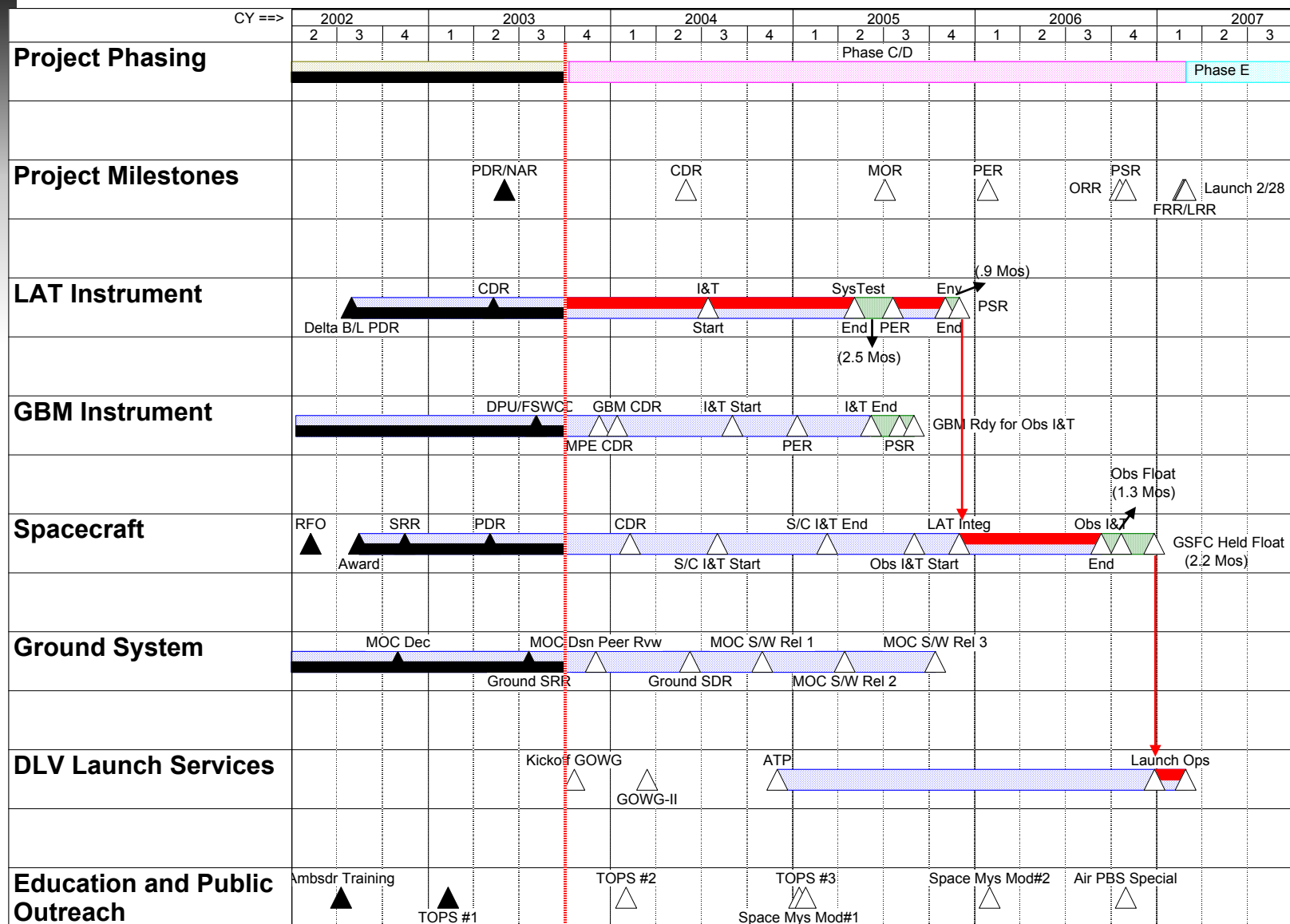
Reasons for LAT Rebaseline

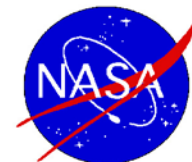
- ▶ ***The Crystal Detector Element effort in France began falling behind in the early part of this year. On April 30th, the French withdrew funding entirely.***
 - *NRL/Swales backup approach was implemented, however all of the slack in the NRL calorimeter production schedules was eroded (3 months lost)*
- ▶ ***Cost growth in LAT subsystems***
 - *Tracker, ACD, Electronics and Mechanical/Thermal*
- ▶ ***At the LAT CDR, 3 significant mechanical issues had not been brought to final resolution***
 - *Cal/grid I/F, X-LAT plate thermal I/F, EM tracker vibration*

The NASA/DOE Joint Oversight Group recently approved the 17.2 M dollar rebaseline for the LAT instrument. The cost is shared equally by NASA and DOE.



Proposed GLAST Master Schedule for 2/07 LRD





GLAST Schedule Float to 2/07 LRD

	Need Date	Planned Date	FLOAT (Calendar Days)
LAT (Critical Path)*			
System Float	07/21/05	05/05/05	76 Days/2.5 Mos
Environmental Test Float	12/01/05	11/03/05	27 Days/.9 Mos
			Total = 103 Days/3.4 Mos
GBM			
MPE Float	10/27/04	10/06/04	20 Days/.7 Mos
MSFC Float	08/22/05	06/07/05	75 Days/2.6 Mos
			Total = 95 Days/3.2 Mos
SPACECRAFT			
Spacecraft Bus Float	09/01/05	03/11/05	173 Days/5.8 Mos
OBSERVATORY			
Observatory Float	10/22/06	09/12/06	39 Days/1.3 Mos
GSFC Float	12/27/06	10/23/06	65 Days/2.2 Mos
			Total = 104 Days/3.5 Mos
CRITICAL PATH TOTAL FLOAT			Total CP = 207 Days/6.9 Mos

* Detailed LAT rebaseline schedules to be completed in October.

This rebaselined LAT schedule has 31 months between LAT CDR and completion of LAT environmental test, including the 3.4 months of reserve.



GLAST Budget



GLAST Budget Impacts Resulting from Recent External Changes



Summary of Changes:

<i>Program Changes</i>	<i>New GLAST Baseline</i>
<i>Current Baseline (Sep '06 LRD)</i>	574.4
<i>LAT Rebaseline</i>	
<i>Malindi (Ku-band change)</i>	
<i>Impacts/Delays to Other Elements</i>	
<i>Contingency</i>	
<i>X-band Ground Station Savings</i>	
<i>New GLAST Baseline</i>	596.8



GLAST Budget (w/additions: LAT rebaseline, Ku add)

SPACECRAFT	0.0	0.0	0.0	0.0	0.0	0.0		0.0	
LAT INSTRUMENT	0.0	0.0	0.0	0.0	0.0	0.0		0.0	
GBM INSTRUMENT	0.0	0.0	0.0	0.0	0.0	0.0		0.0	
PROJECT MANAGEMENT	0.0	0.0	0.0	0.0	0.0	0.0		0.0	
LAUNCH SERVICES	0.0	0.0	0.0	0.0	0.0	0.0		0.0	
MISSION SYSTEM ENGR	0.0	0.0	0.0	0.0	0.0	0.0		0.0	
SCIENCE	0.0	0.0	0.0	0.0	0.0	0.0		0.0	
E/PO	0.0	0.0	0.0	0.0	0.0	0.0		0.0	
GROUND SYSTEM DEVEI	0.0	0.0	0.0	0.0	0.0	0.0		0.0	
MO&DA (10 Years)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RESERVES *	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0
TOTAL R&D	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MPS / SERVICE POOLS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL GLAST	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FULL COST	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



GLAST Full Cost Budget

\$M	Full Cost
GSFC	0.0
Procurements	0.0
Personnel	0.0
Contingency on C.S. (20%, 10% for MO&DA)	0.0
Travel	0.0
Corporate G&A (Process 315)	0.0
Center G&A	0.0
Service Pools (facilities, IT, science & engr)	0.0
MPS	0.0
KSC	0.0
Procurements (L/V)	0.0
Corporate G&A KSC	0.0
MSFC	0.0
Procurements	0.0
Personnel	0.0
Corporate G&A (Assumes 6.5%)	0.0
Center G&A (Assumes 42%)	0.0
Service Pools (Assumes 34%)	0.0
TOTAL	0.0



Total GLAST Mission NOA Impact Phasing

	<u>FY 04</u>	<u>FY 05</u>	<u>FY 06</u>	<u>FY 07</u>	<u>TOTAL</u>
Msn Mgmt	0	0	0	0	0
Sys Engr	0	0	0	0	0
Science	0	0	0	0	0
LAT	0	0	0	0	0
GBM	0	0	0	0	0
Spacecraft	0	0	0	0	0
- Ku-band/Malindi	0	0	0	0	0
Gr. Sys	0	0	0	0	0
- Ku-band/Malindi	0	0	0	0	0
E/PO	0	0	0	0	0
Contingency	0	0	0	0	0
Additional Cost	0	0	0	0	0
Delay L/V ATP	0	0	0	0	0
Rephase S/C Payments	0	0	0	0	0
Rephase MOC Develop.	0	0	0	0	0
MO&DA Reduction (8 mths)	0	0	0	0	0
New Funding Requirements	0	0	0	0	0

The full cost impact associated with a 8 month slip is estimated at \$xM (not included above).



Project vs. LaRC Independent Cost Estimate

\$M	Proj Budget + Reserves	ICE Modal	Delta	ICE 90%	Delta
Spacecraft	0.0	0.0	#####	0.0	#DIV/0!
LAT (Including DOE)	0.0	0.0	#####	0.0	#DIV/0!
GBM	0.0	0.0	#####	0.0	#DIV/0!
Launch Vehicle	0.0	0.0	#####	0.0	#DIV/0!
All Other (Gr Sys, Mgmt, E/PO)	0.0	0.0	#####	0.0	#DIV/0!
Subtotal	0.0	0.0	#####	0.0	#DIV/0!
MO&DA (Including DOE)	0.0	0.0	#####	0.0	#DIV/0!
Total	0.0	0.0	#####	0.0	#DIV/0!

- The total NASA/DOE budget is between the IPAO ICE “modal” and “90%” estimates.
- Costs on this chart are not full cost numbers.

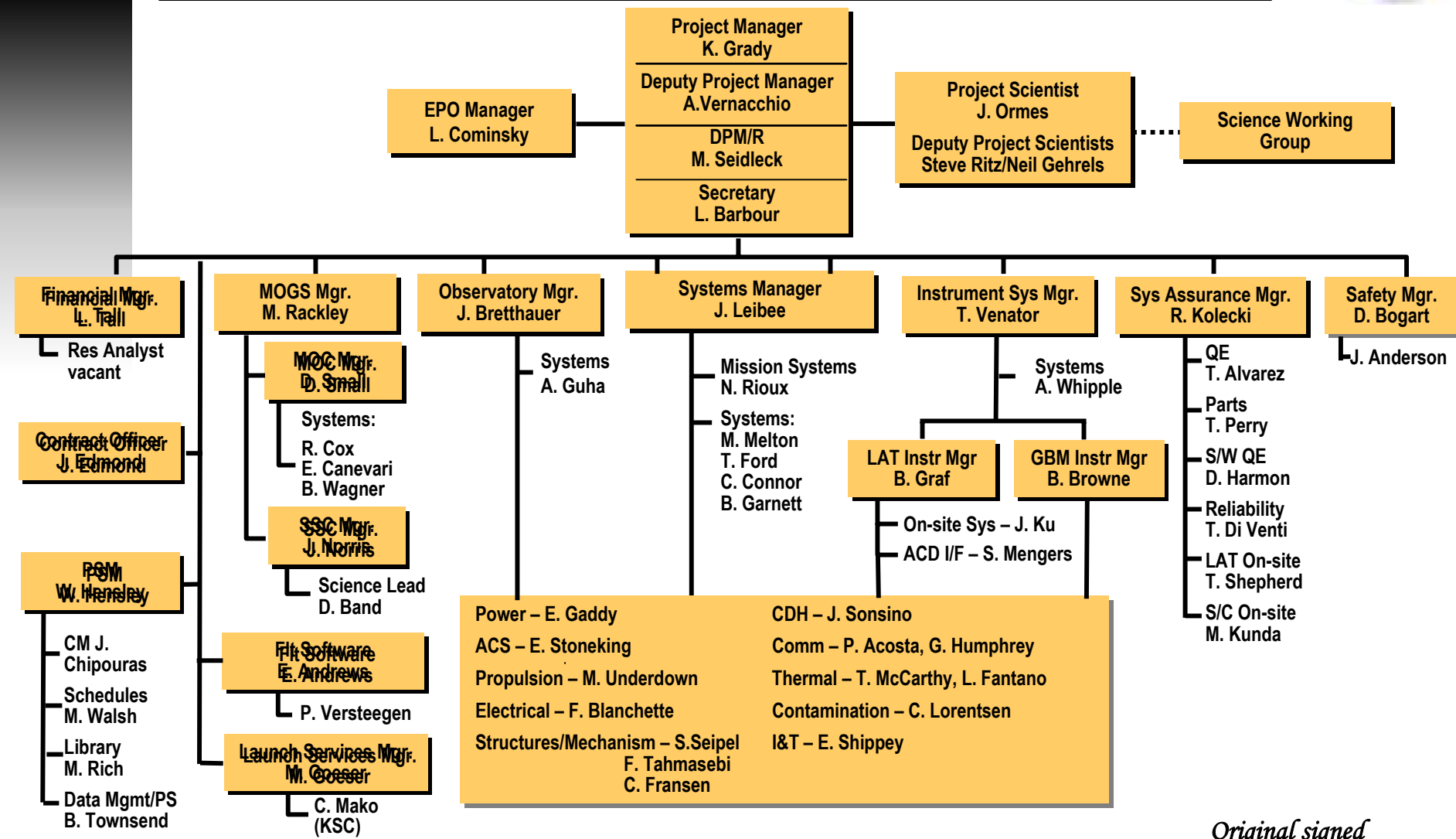


Project vs. RAO Cost Estimates

	Project Budget		RAO Estimates			
	BAU	Full Cost	Lower	Delta	Upper	Delta
Mission Mgmt/Syst Engr/MPS	0	0	0	#DIV/0!	0	#DIV/0!
Spacecraft Bus	0	0	0	#DIV/0!	0	#DIV/0!
MSI&T	0	0	0	#DIV/0!	0	#DIV/0!
LAT (Including DOE)	0	0	0	#DIV/0!	0	#DIV/0!
GBM	0	0	0	#DIV/0!	0	#DIV/0!
Ground System/Science	0	0	0	#DIV/0!	0	#DIV/0!
Launch Vehicle	0	0	0	#DIV/0!	0	#DIV/0!
Other	0	0	0	#DIV/0!	0	#DIV/0!
Subtotal	0	0	0	#DIV/0!	0	#DIV/0!
MO&DA (NASA Only)	0	0	0	#DIV/0!	0	#DIV/0!
Contingency	0	0	0	#DIV/0!	0	#DIV/0!
Total	0	0	0	#DIV/0!	0	#DIV/0!



GLAST Project Organization



Original signed

Kevin Grady
GLAST Project Manager
 September 9, 2003



Mission Overview Outline (cont.)



- ▶ ***Flight Software IV&V***
- ▶ ***Communications Security***
- ▶ ***IT Security***
- ▶ ***Key GLAST Management Plans***
- ▶ ***Documentation Tree***
- ▶ ***Descope Plan***
- ▶ ***Education and Public Outreach***

Note: These topics would be back-up material for the Agency-level Program Management Council.



Independent Verification & Validation



► **Spacecraft**

- *Integrating the IV&V effort with software development team early in program*
 - *IV&V Attended SC SRR, FSW SRR*
 - *IV&V Attended SC PDR, FSW PDR, MPDR*
- *IV&V Under Contract for SC FSW Assessment*
 - *Draft MOA for SC IV&V received 9/29/03*
- *Currently reviewing detailed requirements from Software Requirements Spec*
- *Careful documentation & CM of Swift Code Reuse permits reuse of IV&V efforts in these areas. (Full testing and IV&V testing review to be conducted)*

► **Large Area Telescope**

- *IV&V focused on critical software functionality.*
 - *1553 Interface, Boot and Safety Software*
- *LAT IV&V Tasks*
 - *Software Requirements Analysis, Software Requirements Traceability Analysis, Interface Requirements Analysis , Test Program Analysis*
- *LAT IV&V Findings*
 - *To Date (10/1/03): 50 TIMs received by project in three different groups.*
 - *Current Status: 4 Closed; 1 Closed with Concern (TIM-0031); 31 Resolved, 8 withdrawn, 6 open*



GLAST Communications Security

- ▶ ***NASA has withdrawn its existing communications security guidelines in the wake of 9/11***
- ▶ ***GSFC has established a center committee to establish communications security policy for the center consistent with the current environment***
- ▶ ***The GLAST Systems Manager is a member of the GSFC communications security committee and will have detailed and immediate knowledge of developments in center security policy and their impact on GLAST***
 - *The addition of uplink encryption to the GLAST mission would necessitate spacecraft design changes*
- ▶ ***National Security Telecommunications and Information Systems Security (NSTISS) Policy number 12 for US Space Systems has been examined by the Project and found not to apply to GLAST***
- ▶ ***Features of GLAST:***
 - *Space science basic research data for use in public domain*
 - *No commercial value or national security relevance of GLAST data*
 - *Not a national security asset, resource or critical infrastructure*
- ▶ ***The current GLAST baseline does not include encryption***



IT Security



- ▶ ***GLAST Program fully compliant with NPG 2810.1***
 - *IT Security Plan, IT Risk Management Plan and Contingency Plan developed covering GLAST resources.*
- ▶ ***Ground system will be fully NPG 2810.1 compliant***
 - ***Requires generation of three key IT Security documents:***
 - ***IT Security Plan, IT Risk Management Plan, Contingency Plan***
 - *Documents scheduled to be completed by the Ground CDR June 2004*
 - *IT Security documents will address the entire ground system*
 - *Will be working with IT Security Branch, Code 297, during ground system design phase to ensure security adequately addressed*
 - *Ground system will have to pass independent Code 297 security audit in order to have operational connections established (e.g., system scans)*



Key GLAST Management Plans (1)

- ▶ ***Program Plan (433-PLAN-0008)***
 - *Establishes the baseline for the GLAST Program implementation*
 - *Consistent with the format specified in NPG 7120.5*
 - *Contains GLAST Level 1 requirements*
 - *Presently in routing for signature after multiple iterations of reviews and comments.*
- ▶ ***Project Plan (433-PLAN-0001)***
 - *Establishes the baseline for the GLAST Project implementation*
 - *Consistent with the format specified in NPG 7120.5*
 - *Presently in routing for signature after multiple iterations of reviews and comments.*
- ▶ ***Risk Management Plan (433-PLAN-0002)***
 - *Documents the continuous risk management process implemented by the GLAST Project*
 - *The risk process has been utilized on the Project for over a year*
 - *The GLAST Project Continuous Risk Management Plan is baselined*



Key GLAST Management Plans (2)

► ***GLAST Descope Plan***

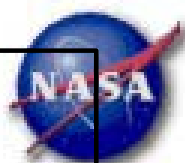
- *Documents management approach to evaluate potential descope decisions*
- *Appendix contains list of presently available descope options*
- *The GLAST Descope Plan has been baselined*

► ***Independent Review Plan***

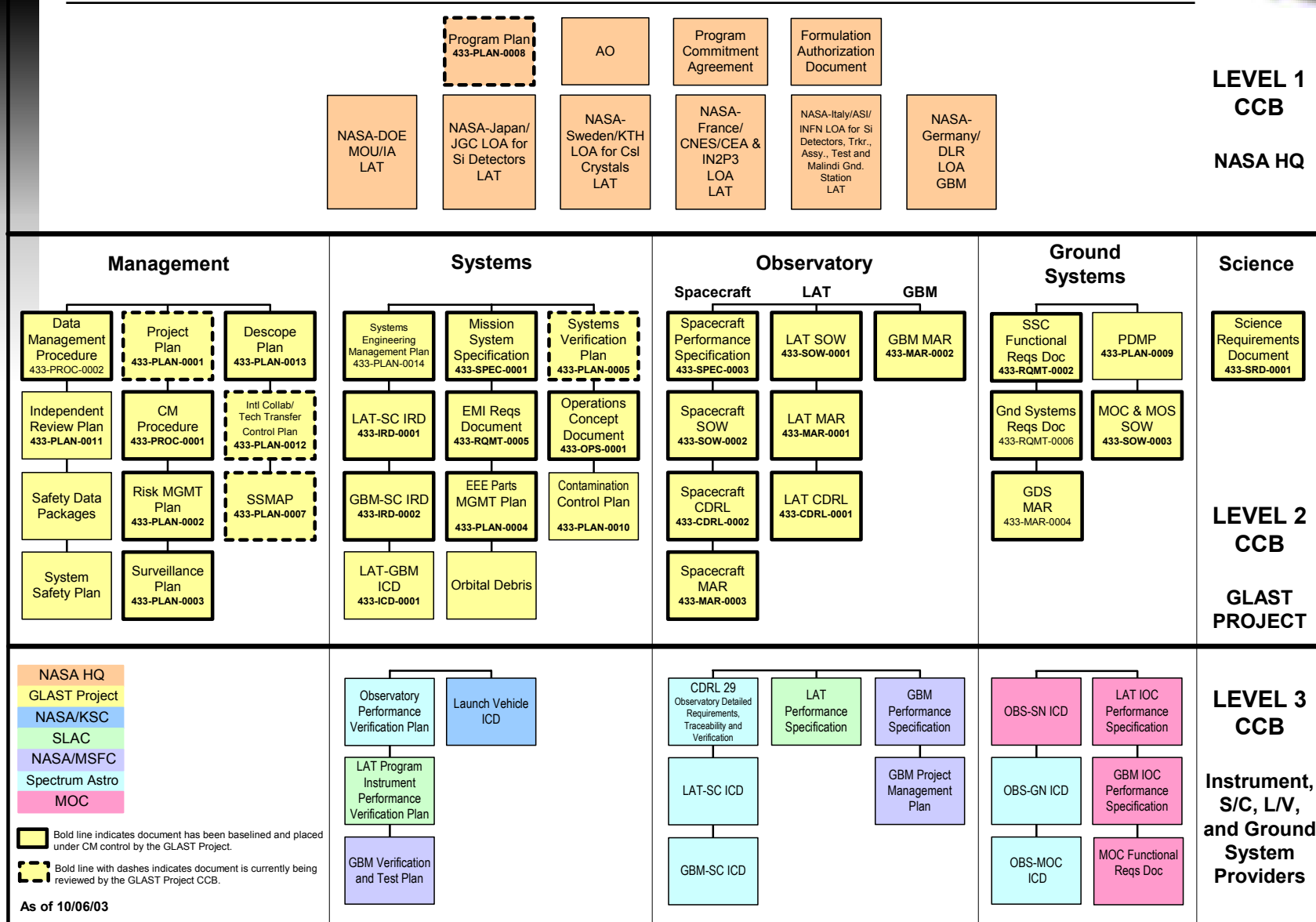
- *Documents the independent reviews and the engineering peer reviews to be conducted for the GLAST mission*
- *Consistent with GPG 8700.4D and 8700.6*
- *Awaiting Code 300 signature*

► ***Program Commitment Agreement***

- *Will be updated with new May 2007 LRD.*



GLAST PROJECT CONFIGURATION MANAGEMENT DOCUMENT TREE



 Bold line indicates document has been baselined and placed under CM control by the GLAST Project.

 Bold line with dashes indicates document is currently being reviewed by the GLAST Project CCB.

As of 10/06/03



Potential GLAST Mission Descope Items (1)

- ▶ *Large Area Telescope*
 - *Reduce number of towers (16 to 14 or 12)*
 - *Accept some out of spec trackers/calorimeters*
 - *Eliminate layers of Csl in calorimeters*
 - *Delete beam test on LAT Calibration Unit*
 - *Delete burst alert processing*
 - *Delete one of the EPU's*
- ▶ *GLAST Burst Monitor*
 - *Delete GBM from mission*
 - *Integrate and fly a reduced set of sensors if schedule or cost pressures evolve*
 - *Fly GBM hardware with reduced testing (instrument-level or satellite-level) if schedule or cost pressures evolve*
 - *No compromises on safety or compatibility related (vibration/emi) testing*
 - *Delete BGO calibration testing at Duke University*



Potential GLAST Mission Descope Items (2)

► **Science**

- *Delete/descope interdisciplinary scientist funding*
- *Descope guest observer program*

► **Spacecraft**

- *Delete propulsion subsystem.*
- *Delete one star tracker*
- *Delete independent safe mode.*
- *Delete autonomous burst alert re-pointing*

► **Launch Vehicle**

- *Examine feasibility of changing to 7920 launch vehicle*

► **Operations and data processing**

- *Reduce mission life to 2 years (minimum requirement)*
- *Delete Science Support Center and have IOCs provide data to high energy community*
- *Reduce functionality or services of SSC: backup Level 1 pipeline, off hours responsiveness to TOO requests, frequent timeline updates, guest investigator support, or rapid data distribution*



GLAST E/PO Program

- ▶ **NASA E/PO group at Sonoma State University provides overall coordination of outreach efforts for GLAST**
 - *Meets all the requirements of the Office of Space Science E/PO Strategic Plan with emphasis on formal and informal education*
- ▶ **Goal: Utilize the observations and scientific discoveries of the GLAST mission to improve the understanding and utilization of science and mathematics concepts for grades 9-12.**
 - *Brings the excitement of mission science and scientists into the high school classroom and community*
 - *Promotes excellence in science, mathematics, engineering and technology education through an extensive program that will reach thousands of educators, tens of thousands of students, and millions in the general population*
 - *Collaborates with the OSS Structure and Evolution of the Universe Education Forum, other SEU missions, and other partners in the OSS Support Network.*
- ▶ **E/PO Lead (Prof. Lynn Cominsky) is an award-winning educator and GLAST Co-investigator**
 - *Independent Evaluation by WestEd: formative, summative, dissemination, and results tracking*



GLAST E/PO Program



- ▶ **Web based materials**
 - *E/PO web site*
 - *Space Mysteries*
 - *SLAC Virtual Visitor's Center*
- ▶ **Printed materials (now in the hands of over 10,000 teachers)**
 - *Educator's guides and posters*
 - *Public brochures*
- ▶ **TOPS Learning Systems Inc. modules**
- ▶ **PBS Nova show on High Energy Astronomy and Black Holes**
- ▶ **Educator training**
 - *Educator Ambassador program (over 3000 teachers trained in 20 states)*
 - *Workshops for AAVSO and at national, regional meetings*
 - *Minority outreach workshops*
- ▶ **GLAST Telescope Network: partners scientists with high-school students and amateurs.**



Independent Review RFA Status

► Total RFA Status

- 125 Total, 15 completed Project review, 28 in Project review, 14 in draft

► SC PDR & SC FSW PDR

- 57 Total, 10 completed Project review with some comments & will be sent to originator when updated, 10 additional responses in review at Project

► LAT CDR

- 37 Total, 6 in review at Project, 1 of the required peer reviews has been completed

► MPDR

- 14 Total, 5 completed Project review with some comments & will be sent to originator when updated, 9 in draft

► GS SRR

- 17 Total, 12 in review at Project, 5 in draft

NONE OF THE RFAs ARE LIENS AGAINST MISSION CONFIRMATION AND WILL BE WORKED OFF PRIOR TO THE MCDR



Summary

- ▶ *GLAST will provide substantial contributions to our knowledge of the high-energy gamma ray universe*
- ▶ *GLAST requirements are well-defined and allocated to elements and subsystems*
- ▶ *Preliminary and detailed implementations developed*
- ▶ *Schedule and budget that addresses the scope and risks of the GLAST mission*
- ▶ *Risk management process and top ten issues process in place*
- ▶ *Management processes, element teams and Project staff in place to execute the GLAST development phase*

GLAST: the high energy astro-particle partnership is ready to proceed into the implementation phase.